INTEROFFICE MEMORANDUM

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SUBJECT: Real-Time Commanding Requirements at Jupiter Encounter for the CRS, LECP, MAG and PLS Investigations

ABSTRACT: Real-time commanding of the fields-and-particles instruments at Jupiter encounter is required: (1) to change instrument configurations in response to rapidly-changing environmental conditions, (2) to perform instrument calibrations in the Observatory and Post-Encounter phases (to reduce CCS words), and (3) to respond to emergencies.

Some of the (predictable) configuration changes require a quick turn-around ($\sim$1 hr) from the time of request to time of transmission. A description of the real-time commanding for CRS, LECP, MAG and PLS is given in as much detail as is now available.

A summary schedule, showing numbers and timing, of anticipated real-time commanding for these investigations is attached.

I. Introduction

In the vicinity of Jupiter, the magnetic field, plasma, and energetic-charged-particle densities, spectra, and composition will be greatly different from those seen in interplanetary space. Moreover, environmental conditions can change rapidly; particle populations can change by a factor of two within five minutes. The magnitude of these parameters and timing of their changes are known only approximately and, to some extent, configuration changes of the instruments based on near-real-time analysis of science data are required for their measurement. In general, however, the required configuration changes can be defined in advance with only the timing of the associated commands determined in near-real time.

It is important to have a quick turnaround ($\sim$1 hour) for these commands from the time of request to time of transmission. It is proposed that pre-specified commands be generated on files well in advance of encounter, approved in principle for transmission, with final approval of the actual transmission time contingent on command traffic and current health of the spacecraft.

Other types of commands that can be generated in advance of encounter include calibration sequences and (some) emergency commands. The different types of commands are discussed in more detail in Section II, which follows; specific commands planned for the CRS, LECP, MAG, and PLS investigations are then described according to command type in Sections III - V.

II. Types of Commands

Before listing specific commands for the individual investigations, a general description of the different types of commands will be given.

A. Pre-specified Configuration Changes.

1. Command Sequences

As the overall intensity of charged-particle fluxes rises on approach to Jupiter, certain configuration changes are necessary in order to avoid saturation and make better use of the available data stream. The specific command sequences to effect these changes (but not their exact timing) can be generated in advance; this type of command sequence is typical of those required for the CRS and LECP investigations.

2. Individual Commands

Because of uncertainties in knowledge of certain features of the Jovian environment (e.g., plasma density) some configuration changes will probably be made using several single commands instead of pre-specified sequences. The exact sequence of the individual commands can't be predicted but a finite library of commands (e.g., the 16 gain-state commands of PLS) can be generated to handle most conditions.

B. Pre-specified Calibrations.

The Voyager Project has agreed in principle to perform calibrations of CRS, LECP, MAG and PLS during the Observatory and Post Encounter phases by real-time commanding. The exact sequences of commands and also their times of transmission can be defined well in advance of encounter and included in mission-operations planning.

C. Pre-specified Emergency Commands.

1. Health of Spacecraft and Instruments

To the extent possible, emergency commands (e.g., CC or power commands controlling instrument on/off, supplemental and replacement heaters) should be considered in advance of encounter together with a description of procedures for their use. The emergency procedures should include commands to assess instrument performance; these are usually SC or science commands which need to be generated on files before encounter.

2. Critical Science Data

The definition of emergencies should include conditions which threaten loss of critical science data. Procedures to correct such conditions should be considered in parallel with those planned to maintain spacecraft health and the required commands should be generated and maintained on files.

D. "Normal" Commands (not pre-specified).

Because of limitations in the predictability of the Jovian environment coupled with the impracticality of generating all possible commands in advance, certain commands will have to be generated and approved after their need becomes known. Even in an emergency, this will slow down the command process (nominal turnaround for non-emergency commands is 48 hr). As far as possible, therefore, real-time commanding contingencies should be planned long in advance of encounter.

III. Configuration Changes; Specific Real-Time Commands

A. CRS

The FDS-08 program for Jupiter encounter has a table (CRSSCT) which allows the CRS instrument to cycle among four different commandable configurations. This capability extends the energy ranges, particle identification, and accurate energy measurement of the experiment at encounter. CRSSCT consists of 4 sub-tables of 9 words each which can be modified by ST 21 AJ commands.

The 36 CRS commands stored in this table at any given time are called a "format". There are five CRS formats, designated A through E, planned for Jupiter encounter. As the overall event rates change near Jupiter, use of these different formats will optimize the measurements by avoiding saturation in various channels making best use of the available data stream. It is planned that the changes from one format to another on JST will be accomplished by real-time commanding.

The following table gives for JST an overall view of the planned

times of CRS format changes and the number of commands required for each format change:

FORMAT	TIME FROM CLOSEST APPROACH	# COMMANDS REQUIRED
Load Format A	~ -30d	24
Initiate Cycling Within Format A	~ -9d	7
A -> B	~ -4d	6
B -> C	~ -3d	6
C -> D	~ -48h	1
D -> E	~ -28h	1
E -> D	~ +21h	1
D -> C	~ +34h	1
C -> B	~ +4d	6
B -> A	~ +7d	6
A -> Cruise	~ +10d	16

The actual commands planned for these format changes are:

FORMAT	COMMANDS
Load Format A (~ -30d)	ST 21 AJ 01 000000
	ST 21 AJ 11 000000
	ST 21 AJ 21 000000
	ST 21 AJ 31 000000
	ST 21 AJ 02 020000
	ST 21 AJ 04 043770
	ST 21 AJ 05 053740
	ST 21 AJ 06 073000
	ST 21 AJ 07 100700
	ST 21 AJ 08 123600
	ST 21 AJ 09 130000
	ST 21 AJ 13 033770
	ST 21 AJ 15 050430
	ST 21 AJ 17 100600
	ST 21 AJ 18 120000
	ST 21 AJ 19 130050
	ST 21 AJ 22 023770
	ST 21 AJ 23 030000
	ST 21 AJ 24 040000
	ST 21 AJ 25 052740
	ST 21 AJ 26 072000
	ST 21 AJ 27 100400
	ST 21 AJ 28 123770
	ST 21 AJ 37 100200

FORMAT	COMMANDS
Initiate Cycling Within Format A (~ -9d)	SC 21 AF 11001 SC 21 AF 06240 SC 21 AF 08200 ST 21 AJ 01 150001 ST 21 AJ 11 010000 ST 21 AJ 21 013770 ST 21 AJ 31 150001
A -> B (~ -4d)	SC 21 AF 08240 ST 21 AJ 06 073400 ST 21 AJ 07 100760 ST 21 AJ 17 100660 ST 21 AJ 27 100460 ST 21 AJ 37 100260
B -> C (~ -3d)	ST 21 AJ 02 020770 ST 21 AJ 03 080600 ST 21 AJ 06 073500 ST 21 AJ 11 013170 ST 21 AJ 12 023170 ST 21 AJ 14 082500
C -> D (~ -48h)	ST 21 AJ 24 043610
D -> E (~ -28h)	ST 21 AJ 23 033610
E -> D (~ +21h)	ST 21 AJ 23 030000
D -> C (~ +34h)	ST 21 AJ 24 040000
C -> B (~ +4d)	ST 21 AJ 02 020000 ST 21 AJ 03 150001 ST 21 AJ 06 073400 ST 21 AJ 11 100000 ST 21 AJ 12 020000 ST 21 AJ 14 150001 * SC 21 AF 08240

* Must follow the six ST commands.

FORMAT	COMMANDS
B -> A (~ +7d)	SC 21 AF 08200 ST 21 AJ 06 073000 ST 21 AJ 07 100700 ST 21 AJ 17 100600 ST 21 AJ 27 100400 ST 21 AJ 37 100200
A -> Cruise (~ +10d)	ST 21 AJ 01 000000 ST 21 AJ 11 000000 ST 21 AJ 21 000000 ST 21 AJ 31 000000 SC 21 AF 01000 SC 21 AF 02000 SC 21 AF 03000 SC 21 AF 04000 SC 21 AF 05200 SC 21 AF 06000 SC 21 AF 07200 SC 21 AF 08200 SC 21 AF 10040 SC 21 AF 11000 SC 21 AF 12000 SC 21 AF 13012

In addition to the above specified sequences of CRS configuration-change commands, it will be useful to have a number of individual CRS commands on a file for quick-turnaround use at encounter. These could include, for example, the command to initiate calibration, "No-Op" commands for the CRS table, and single-action commands for desired encounter configurations. Such commands would all be of the forms:

SC 21 AF XXXXX
SC 21 AG
SC 21 AH
ST 21 AJ nn XXXXXX

CRS power commands (CC 21 XX) will be discussed in Section V, "Emergency Commands."

B. LECP

The LECP investigation employs two detector systems, the Low Energy Particle Telescope (LEPT) and the Low Energy Magnetospheric Particle Analyzer (LEMPA). The LEPT system is designed to identify individual charged particles and to provide accurate energy measurements at relatively low event rates. LEMPA is designed to provide measurements at very high event rates with a loss in energy resolution and particle identification. At Jupiter the event rates will vary from low, cruise-type rates at the beginning of the encounter period to very high rates near closest approach. In order to provide optimal use of the LECP data stream as the spacecraft approaches Jupiter, several changes in instrument configuration are planned to shift the operation in several stages from primarily LEPT to primarily LEMPA (and the reverse, post-encounter). The actual timing of these commands will be determined from near-real-time analysis of LECP science data. The motor-step rate is planned to be one step per six seconds throughout Jupiter encounter (±30d).

The following commands are those planned for JST:

TIME FROM CLOSEST APPROACH TO JUPITER	LECP/JST CONFIGURATION-CHANGE COMMANDS
~ -30d	SC 25 AH 4220
~ -5d	SC 25 AH 1760 SC 25 AH 4220
~ -4½d	SC 25 AH 1720 SC 25 AH 4220
~ -4d	SC 25 AH 2576 SC 25 AH 4220
~ -2½d	* SC 06 BB XXXXXX * SC 25 AH 7076 * SC 25 AH 7072 * SC 25 AH 4220 * SC 06 BB XXXXXX
~ -2d	SC 25 AH 7073 SC 25 AH 4220
~ -18h	SC 25 AH 0000 SC 25 AH 7001 SC 25 AN 1 SC 25 AH 4220
~ +18h	SC 25 AH 1720 SC 25 AH 7073 SC 25 AN 0 SC 25 AH 4220

TIME FROM CLOSEST APPROACH TO JUPITER	LECP/JST CONFIGURATION-CHANGE COMMANDS
~ +1d	* SC 06 BB XXXXXX
	* SC 25 AH 7076
	* SC 25 AH 7072
	* SC 06 BB XXXXXX
	SC 25 AH 2616
	SC 25 AH 4220
~ +3 to +10d	SC 25 AH 3217
	SC 25 AH 4220
~ +11d	SC 25 AH 1777
	SC 25 AH 6072
	SC 25 AH 4220
~ +30d	SC 25 AH 4200

* Note: the times for the calibrations at -2½d and +1d can be planned in advance so that the data mode commands, SC 06 BB XXXXXX (which are required to move the LECP calibration data to a higher engineering deck) may be verified to be compatible with the current encounter data mode.

In addition to the above sequences of commands to change LECP configuration, it will be useful to have a file of individual LECP commands for quick-turnaround use. These could include, for example, motor-step commands and other LECP commands to effect either planned encounter configurations or alternate ones. These commands will be included in the following forms:

SC 25 AH XXXX
SC 25 AN X

LECP power commands (CC 25 XX) will be discussed in Section V, "Emergency Commands." Calibrations will be discussed in Section IV.

C. MAG

The instrument of the Magnetic Fields Investigation is designed with an automatic-ranging feature that will handle any expected fields at Jupiter. A command file of individual MAG commands should be generated, however, to include commands that could be used to assess the behavior of the instrument or change its configuration in other ways, if found necessary. These commands would be of the forms:

SC 35 AI XXXXXX
SC 35 AO XXXXXX

MAG power commands and real-time calibrations are discussed in Sections IV and V.

D. PLS

It is possible that no PLS configuration-change commands need to be transmitted. During the period of approximately Jupiter ± 7 days, a continuous PLS measurement sequence will be in operation under control of the CCS. Gain states will be pre-set by the initial states within the FDS load. Although these pre-planned on-board operations conceivably could suffice for the entire encounter, realistically it is expected that at least some real-time gain-state commands will be needed.

The PLS positive-ion and electron modes can saturate at Jupiter in several ways:

a) Changes in plasma conditions may occur upon crossing the bow shock ($\sim$ J - 7d on JST) requiring gain-state commands.

b) Further changes in densities may occur at a possible internal shock or magnetopause at $\sim 50\ R_J$.

c) Because of the periodic nature of the Jovian magnetosphere as seen at the spacecraft, it may be necessary to change gain states in response to large periodic changes in plasma conditions. Approximately every five hours (within the inner magnetosphere) the spacecraft will cross the magnetic equator, a region where sharp changes in plasma density may occur. The need for corresponding changes in gain may be seen during early crossings of this 0° magnetic latitude.

d) When crossing the satellite orbits it may be desirable to saturate the peaks of the abundant species by increasing to maximum gain in order to search for rare species (e.g., sulfur at Io).

The automatic measurement sequence under CCS control ($\sim$ J ± 7d) includes "DC-return" configurations designed to measure plasma at energies outside of the normal range. At greater distances from Jupiter it may be desirable to make DC-return measurements by real-time commanding to respond to unusual-appearing plasma spectra/conditions.

The entire complement of PLS commands numbers only 32 of which half are gain-state commands. These 32 commands can easily be generated on a file which could then be accessed for any PLS configuration or gain-state change. It is anticipated that not more than about 4 commands per day (mainly gain-state changes) will be needed within the magnetosphere. If large density changes occur right at the magnetic equator, however, several commands may be required every five hours for a few days (these commands and their timing could be predicted up to $\sim$ 1 day in advance).

IV. Calibrations, Observatory and Post-Encounter Phases

The Voyager Project has agreed, in principle, to perform calibrations during the Observatory and Post-Encounter phases by real-time commanding (in order to save CCS words).

Project guidelines have already been written that limit the total number and frequency of fields-and-particles calibration commands (90, 1/wk), and the duration of the calibrations (several hours for up to 90 commands).

These calibration commands and their timing will be generated and checked out ahead of time; it will probably be desirable to generate all of these on one command file. The time of transmission of the calibrations will be scheduled well in advance; these calibrations are not of a quick-turnaround nature.

The exact sequences of calibration commands have not yet been defined but probably will be very close to the commands listed in:

A. LECP calibration (similar to Block called PESCAL).

~ 5 commands of the following forms;

SC 06 BB XXXXXX
SC 25 AH XXXX

B. MAG calibration (similar to Block 6.2, Option c).

~ 40 commands of the following forms;

SC 35 AI XXXXXX
SC 35 AO XXXXXX

* CC 1C / CC 1CR

* Note: The CC 1C commands, if used to energize the MAG boom-alignment coil, are the only calibration commands that make significant power changes (15 w). These CC commands may not be needed but if they are, they will be included with the SC calibration commands and also will be scheduled well in advance of use.

C. PLS calibration (similar to Block 6.5, Option b).

~ 40 commands of the following forms;

SC 32 AJ XX
SC 32 AL XXX

D. CRS

The command which initiates CRS calibration will be included in a contingency/emergency file and used only to assess unusual instrument behavior.

V. Emergency Commands

This class of commands includes those concerned with maintaining instrument and spacecraft health and also commands associated with maintaining high-value science in the case of incorrect instrument configurations. Such configurations can occur for a variety of reasons including totally unexpected environments, radiation-induced changes, subtle sequencing problems, and others.

A. Predefined Emergency Commands.

These will include the "Contingency" commands being presently defined in coordination with members of the Spacecraft Team.

Others could include sequences of commands designed to restore nominal instrument instrument configurations (initializing commands at the start of a new CCS load, for example, in case of a CCS abort in the previous load).

These commands will include, in addition to the types listed in the previous Sections, power (CC) commands. CC commands may be needed to turn instrument power on and off, change supplemental and replacement heater configurations, and to assess unusual instrument performance.

B. "Normal" Emergency Commands (not predefined).

Because not all circumstances are predictable and because it is impractical to generate all possible commands on files ahead of time, certain emergency commands may have to be generated in a short time in response to sudden instrument/spacecraft problems. This implies that the capability for a quick turnaround including command generation must exist for critical phases of the mission.

Other "normal" (not predefined) commands may not require as quick a turnaround but some of these commands may assume emergency characteristics in proportion to their proximity to Jupiter.

VI. Summary Chart (Number and Schedule of RT Commands)

Attached to this memorandum is a summary chart giving the planned number and timing of the real-time commands planned for JST at Jupiter. The acronyms used in the chart mean:

DOY	Day of Year
OBS	Observatory Phase of Mission
FE 1	Far Encounter 1
FE 2	Far Encounter 2
NE	Near Encounter
PE	Post Encounter
CRS	Cosmic Ray Subsystem
LECP	Low Energy Charged Particles investigation
MAG	Magnetic Fields investigation
PLS	Plasma investigation

The times for the mission phases for JST are defined on the chart.

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JST Jupiter Encounter

Real-Time-Commanding Requirements for CRS, LECP, MAG, PLS

□ = Calibration, # of commands

○ = Configuration Change, # of commands